

A checklist of subterranean arthropods of Iran

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Abstract

Understanding subterranean biodiversity is important, yet vast regions of the world remain poorly explored. Here, we provide the first step towards cataloguing the subterranean arthropods of Iran. After review and analysis of the available literature and the examination of samples collected by us from Iranian caves, we listed 89 cavernicolous species (from 42 caves and 5 karstic springs) belonging to four arthropod subphyla: Chelicerata (1 class, 4 orders, 36 species), Crustacea (2 classes, 3 orders, 15 species), Hexapoda (2 classes, 5 orders, 34 species) and Myriapoda (2 classes, 3 orders, 4 species).

Keywords

Cave, fauna, Middle East, Zagros, troglotauna

Introduction

Although relatively poorly studied in comparison with the epigeal ecosystems, subterranean ecosystems show a rather high biodiversity at the global scale. Globally, over 7000 aquatic subterranean dwellers have been catalogued (Botosaneanu 1986), but unfortunately, such data are not available for the terrestrial subterranean fauna. It is likely that subterranean habitats harbor even larger numbers of terrestrial species, e.g. Coleoptera alone includes more than 1927 underground-limited species (Gibert and Deharveng 2002, Juberthie and Decu 1998). Culver and Holsinger (1992) proposed a potential biodiversity of about 50,000 to 100,000 obligate terrestrial subterranean species on the basis of nested regional estimates.

In spite of more than a century of taxonomic and biogeographic studies, large-scale patterns of diversity of the obligate cave-dwelling fauna have remained obscure. The two major apparent determinants of biodiversity for the subterranean terrestrial fauna, i.e. productivity and habitat availability, are the same as for many other faunas (Hawkins et al. 2003, Turner and Hawkins 2004). Culver et al. (2003) hypothesized a connection between surface productivity and the amount of food available in caves: in nearly all caves, there is no significant chemoautotrophy so that all available food results from the surface productivity. Hotspots are most commonly referred to as areas of high biodiversity, followed by areas of high productivity (Briscoe et al. 2016). There are potential subterranean hotspots in the karst regions of western Caucasus in Georgia and possibly the Tien Shan Mountains in Kyrgyzstan. Although biologically poorly-studied, based on their positive relationship to the productivity maps and the presence of major cave regions they seem to be promising research subjects (Gvozdetski et al. 1994, Klimchouk 2004a, b). These regions are the closest to Iran which somehow have been studied in term of caves fauna. There are a lot of similarities between them and the north and western parts of Iran. Based on the studies conducted on these regions as well as some sporadic studies on Iranian caves in the mentioned areas, we could consider that there are some hotspots there. From east of Kyrgyzstan to the eastern coast of the Asian continent, the climate is probably too dry to support any subterranean hotspots (Culver et al. 2006).

Covering 164.8 million hectares in western Asia at the interface between three zoogeographic realms, Palearctic, Oriental (Indo-Malayan) and Afrotropical (Ethiopian), Iran is situated at the conjunction of three climatic zones: the Mediterranean, the arid West Asian, and the temperate humid/semi-humid Caspian zone. Nevertheless, it lies predominantly in an arid environmental zone. The Zagros and Alborz Mountains are the two main mountain chains in western and northern Iran, which comprise nearly a third of the Iranian land area. Geologically, Iran is a part of the Alpine-Himalayan orogenic belt, divided into five major structural zones: a) Zagros Range, b) Sanandaj-Sirjan Range, c) Central Iran, d) East and South-East Iran and e) Alborz and Kopet-Dagh Ranges. However, more detailed divisions exist. The number of described caves is more than 2000 (Raeisi et al. 2012), with many more to be added.

During the last decade, several faunistic studies have been carried out in Iran, resulting in new records of already known species, as well as the descriptions of many new ones. However, despite the vast amount of collected faunistic data, the Iranian subterranean fauna remains inadequately known, and most reported species from the caves are in fact troglloxenes (Esmaeili-Rineh and Sari 2013). Nevertheless, 16 obligate cave-dwellers are reported from Iran, of which as many as 13 have been described since 2013. Fifteen species of these troglobionts are restricted to Iran. The only known troglobiotic vertebrates are three fish species: *Garra typhlops* (Bruun & Kaiser, 1944), *G. lorestanensis* Mousavi-Sabet & Eagderi, 2016 and *Paracobitis smithi* Smith, 1976 (Cypriniformes) (Farashi et al. 2014, Mousavi-Sabet and Eagderi 2016). Troglobiotic invertebrates include a spider, a diplopod and 11 crustaceans. In this paper, we aim to provide the first checklist of Iranian subterranean arthropods, based on the available literature and our unpublished material.

Material and methods

Unique adaptations of troglofauna have evolved in relations to the significant characteristics of subterranean environments such as caves, e.g. darkness, constant climatic conditions and restricted food supply. Based on their life style and adaptations to the conditions of the unique habitat, cave organisms (troglofauna) are divided into three categories: 1) troglobionts (organisms that display characteristics of troglomorphism, such as depigmentation and loss of eyes, and are considered “obligatory” residents of the underground environment), 2) troglophiles (organisms that can live and complete their life cycle either in the cave or in the surface; some biospeleologists subdivide this group into the eutroglophiles and subtroglophiles) (Gavish-Regev et al. 2016, see Sket 2008); 3) trogloxenes (organisms only occurring sporadically in hypogean habitat and unable to establish a subterranean population that habitually enter caves but must return periodically to the outside for certain of their living requirements, usually food) (Sket 2008, Romero 2009, Culver and Pipan 2009). We classified cave organisms into the mentioned three groups, based on the classification used in the available literature or on our own observations. Troglomorphic and non-troglomorphic species that were found in all cave zones throughout the year are classified as troglophiles. Trogloxenes were found either around cave entrances or within the entrance zone of smaller caves. Ectoparasites of bats were not categorized, however, they could be considered as troglophiles or trogloxenes. Major structural zones of Iran and the distribution of all troglobionts have been shown in Figure 1. Specimens from caves were collected by means of diverse sampling items (e.g. the plankton net, small hand net and aspirator), and placed directly into 96% ethanol. The collected specimens were brought to the laboratory and identified using identification keys and also with the assistance of specialists. Records of undetermined species are not referenced in this catalog. Material is deposited in the Zoological Museum of University of Tehran (ZUTC) and in the Collection of Biology Department, Zoological Museum of Shiraz University, Shiraz, Iran (ZM CBSU).

List of species

Phylum Arthropoda von Siebold, 1848

Subphylum Chelicerata Heymons, 1901

Class Arachnida Lamarck, 1801

Order Araneae Clerck, 1757

Based on the World Spider Catalog (2016), 45,987 species of spiders, grouped in 3,985 genera and 114 families have been described so far. To date, more than 600 spider species of 243 genera and 48 families have been recorded from Iran (Zamani et al. 2016). Only a few recent publications deal exclusively with the cave spider fauna of Iran (Marusik et al. 2014, Malek Hosseini et al. 2015a, b), while in previous reports only scattered

records are provided (e.g. Brignoli 1970, Senglet 2008, Moradmand and Jäger 2011). Here, we have listed 29 species from 15 families and 21 genera, most of which have been classified as edaphic troglaphiles and troglaxenes, and one troglobiont.

Family Agelenidae C. L. Koch, 1837

***Tegenaria lenkoranica* (Guseinov, Marusik & Koponen, 2005)**

Status: **troglaxene**.

Records: Roodafshan Cave (Tehran Province) (Zamani et al. 2014), Shirabad Cave (Golestan Province) (present study).

***Tegenaria zamanii* Marusik & Omelko, 2014**

Status: **troglaphile**.

Records: Shirabad Cave (Golestan Province) (Marusik et al. 2014, Marusik and Zamani 2015).

Family Eutichuridae Lehtinen, 1967

***Cheiracanthium mildei* L. Koch, 1864**

Status: **troglaxene**.

Records: Nevel Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2015b).

Family Gnaphosidae Pocock, 1898

***Anagraphis pallens* Simon, 1893**

Status: **troglaphile**.

Records: Gakal Cave, Neyneh Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2015b).

Family Liocranidae Simon, 1897

***Mesiotelus scopensis* Drensky, 1935**

Status: **troglaxene**.

Records: Nevel Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2015b).

Family Linyphiidae Blackwall, 1859

***Leptyphantes iranicus* Saaristo & Tanasevitch, 1996**

Status: **troglophile**.

Records: Shirabad Cave (Golestan Province) (Marusik et al. 2014).

***Megaleptyphantes camelus* (Tanasevitch, 1990)**

Status: **trogloxene**.

Records: Unnamed cave (Alborz Province) (present study).

***Palliduphantes sbordonii* (Brignoli, 1970)**

Status: **troglophile**.

Records: Ab Ask Cave (Mazandaran Province) (Brignoli 1970).

***Sengletus latus* Tanasevitch, 2009**

Status: **troglophile**.

Records: Deh Sheikh (Pataveh) Cave, Nevel Cave, Chek Cave, Tikow (Tang-e Tikab) Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2015b).

Family Oonopidae Simon, 1890

***Trilacuna qarzi* Malek Hosseini & Grismado, 2015**

Status: **troglobiont**.

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2015a, b); Fig. 1, locality 2.

Family Oxyopidae Thorell, 1870

***Oxyopes lineatus* Latreille, 1806**

Status: **trogloxene**.

Records: Nevel Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2015b).

Family Pholcidae C. L. Koch, 1850***Artema doriai* (Thorell, 1881)**

Status: **trogloxene / troglophile.**

Records: Behesht Makan Cave, Palangan cave (Fars Province) (Malek Hosseini et al. 2015b).

***Pholcus armeniacus* Senglet, 1974**

Status: **troglophile.**

Records: Unidentified caves (Western Azarbayjan Province) (Senglet 2008).

***Pholcus arsacius* Senglet, 2008**

Status: **troglophile.**

Records: Unidentified caves (Southern Khorasan Province) (Senglet 2008).

***Pholcus elymaeus* Senglet, 2008**

Status: **troglophile.**

Records: Unidentified cave (Kordestan Province) (Senglet 2008).

***Pholcus medicus* Senglet, 1974**

Status: **troglophile.**

Records: Unidentified caves (Eastern Azarbayjan and Mazandaran Provinces) (Senglet 2008).

***Pholcus parthicus* Senglet, 2008**

Status: **troglophile.**

Records: Unidentified caves (Northern Khorasan Province) (Senglet 2008).

***Spermophora persica* Senglet, 2008**

Status: **troglophile.**

Records: Unidentified cave (Kordestan Province) (Senglet 2008).

***Spermophora senoculatoides* Senglet, 2008**

Status: **troglophile.**

Records: Unidentified caves (Kordestan Province) (Senglet 2008).

Family Salticidae Blackwall, 1841***Plexippoides flavescens* (O. P.-Cambridge, 1872)**

Status: **trogloxene**.

Records: Unnamed cave (Alborz Province) (present study).

Family Scytodidae Blackwall, 1864***Scytodes thoracica* (Latreille, 1802)**

Status: **trogloxene**.

Records: Tikow (Tang-e Tikab) Cave (Fars Province) (Malek Hosseini et al. 2015b).

Family Segestriidae Simon, 1893***Segestria mirshamsii* Marusik & Omelko, 2014**

Status: **trogloxene**.

Records: Shirabad Cave (Golestan Province) (Marusik et al. 2014).

Family Sicariidae Keyserling, 1880***Loxosceles rufescens* (Dufour, 1820)**

Status: **troglophile**.

Records: Charkhab Cave (Fars Province) (Sadeghi et al. in press).

Family Sparassidae Bertkau, 1872***Spariolenus iranomaximus* Moradmand & Jäger, 2011**

Status: **troglophile**.

Records: Khofash Cave (Ilam Province) (Moradmand and Jäger 2011).

***Spariolenus zagros* Moradmand & Jäger, 2011**

Status: **troglophile**.

Records: Kenesht Cave (Kermanshah Province) (Moradmand and Jäger 2011), Dalkhoon Cave (Fars Province) (Malek Hosseini et al. 2015b).

Family Tetragnathidae Menge, 1866***Metellina merianae* (Scopoli, 1763)**

Status: **troglophile**.

Records: Shirabad Cave (Golestan Province) (Marusik et al. 2014).

***Metellina orientalis* (Spassky, 1932)**

Status: **troglophile** (this species was observed the whole year in deep parts of Gakal Cave)

Status: **trogloxene** (in other caves it just observed near entrances)

Records: Nevel Cave, Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province), Chek Cave, Tikow (Tang-e Tikab) Cave (Fars Province) (Malek Hosseini et al. 2015b).

Family Theridiosomatidae Simon, 1881***Theridiosoma gemmosum* (C. L. Koch, 1877)**

Status: **troglophile**.

Records: Shirabad Cave (Golestan Province) (Marusik et al. 2014), Nevel Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2015b).

Family Uloboridae Thorell, 1869***Octonoba yesoensis* (Saito, 1934)**

Status: **trogloxene**.

Records: Shirabad Cave (Golestan Province) (Marusik et al. 2014).

Order Pseudoscorpiones Haeckel, 1866

According to our own unpublished data, 56 species and subspecies of pseudoscorpions, from 12 families are known from Iran, of which, only one troglophile species is listed here.

Family Chernetidae Menge, 1855***Megachernes pavlovskyi* Redikorzev, 1949**

Status: **troglophile**.

Records: Deh Sheikh (Pataveh) Cave (Kohgiluyeh and Boyer-Ahmad Province) (Christophoryová et al. 2013), Karafto Cave (Kordestan Province), Kila Sefid Cave (Kermanshah Province) (Mirmoayedi et al. 2000).

Subclass Acari Leach, 1817

This subclass is with probably over 45,000 described species and has very complex systematics. There are more than 1,000 described species reported from caves with some being troglomorphic or troglophiles to some degree, generally showing reduction or loss of eyes and depigmentation, as well as elongation of appendages and well-developed sensory setae (Romero 2009). No detailed study of Acari in caves (e.g., as ectoparasites or guanobionts) has been done in Iran so far, and only five species of bat's ectoparasites are listed in here. We have collected several undetermined species that some of them are guanophilic and some other are associated with beetles.

Order Ixodida Leach, 1815

Family Ixodidae Koch, 1844

***Ixodes simplex* Neumann, 1906**

Status: **bat ectoparasite.**

Records: Kiler Cave (Kohgiluyeh and Boyer-Ahmad Province), Tadovan Cave (Fars Province) (Malek-Hosseini et al. 2016b).

***Ixodes vespertilionis* Koch, 1844**

Status: **bat ectoparasite.** This species shows certain degree of troglomorphism, such as extremely elongated appendages and well-developed sensory setae.

Records: Mahi-Dasth Limy Cave (Kermanshah Province) (Vatandoost et al. 2010), Deh Sheikh (Pataveh) Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek-Hosseini et al. 2016b).

Order Mesostigmata Canestrini, 1891

Family Spinturnicidae Oudemans, 1902

***Meristaspis lateralis* (Kolenati, 1856)**

Status: **bat ectoparasite.**

Records: Bishapur, cave at the Sasan spring (Fars Province) (Benda et al. 2012).

***Spinturnix myoti* (Kolenati, 1856)**

Status: **bat ectoparasite.**

Records: Tadovan Cave (Fars Province) (Benda et al. 2012), Kiler Cave (Kohgiluyeh and Boyer-Ahmad Province), Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek-Hosseini et al. 2016b).

***Spinturnix psi* (Kolenati, 1856)**

Status: **bat ectoparasite.**

Records: Tadovan Cave (Fars Province), Bishapur Cave (Fars Province), Dashkahun Cave (Ardabil Province) (Benda et al. 2012), Kiler Cave (Kohgiluyeh and Boyer-Ahmad Province), Gakal cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek-Hosseini et al. 2016b).

Subphylum Myriapoda Latreille, 1802**Class Chilopoda Latreille, 1817**

Approximately 3,000 species of centipedes are found in the class Chilopoda (Vazirianzadeh et al. 2007). About 60 species have been found in caves (Romero 2009). No checklist is available regarding the number of species in Iran; here we list two troglophile species. Specimens were identified by Dr. Marzio Zapparoli (Tuscia University, Viterbo, Italy.)

Order Geophilomorpha Pocock, 1896**Family Mecistocephalidae Bollman, 1893*****Mecistocephalus evansi* Brolemann, 1922**

Status: **troglophile.**

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (present study).

Order Lithobiomorpha Pocock, 1895**Family Lithobiidae Newport, 1844*****Lithobius erythrocephalus cronebergii* Sseliwanoff, 1881**

Status: **troglophile.**

Records: Deh Sheikh (Pataveh) Cave, Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (present study).

Class Diplopoda De Blainville in Gervais, 1844

About 10,000 species of millipedes have been described, of which, about 200 species in five orders have been reported from caves (Romero 2009). Enghoff and Moravvej (2005) listed 50 species of Iranian millipedes, of which only one species was reported from a cave. Here, we list two species, including one troglobiont.

Order Spirostreptida Brandt, 1833

Family Cambalidae Hoffman, 1979

***Chiraziulus kaiseri* Mauries, 1983**

Status: **troglophile**.

Records: Sarab Cave (Hamadan Province) (Enghoff and Moravvej 2005).

***Chiraziulus troglopersicus* Reboleira, Malek Hosseini, Sadeghi & Enghoff, 2015**

Status: **troglobiont**.

Records: Neyneh Cave (Kohgiluyeh and Boyer-Ahmad Province) (Reboleira et al. 2015); Fig. 1, locality 3.

Subphylum Crustacea Brünnich, 1772

Class Malacostraca Latreille, 1802

Order Amphipoda Latreille, 1816

This subphylum is constituted of about 52,000 known living marine, freshwater and terrestrial species with worldwide distribution (Martin and Davis 2006). It is by far the richest and the most diverse group in subterranean waters. A literature search yielded more than 4,800 species of cave, phreatic, and anchialine crustaceans from all over the world, including marine, freshwater, and terrestrial ones (Romero 2009). By far the most species-rich crustacean groups are Amphipoda and Copepoda, although Decapoda (due to their size) are probably the most obvious (Holsinger 1993, White and Culver 2012). With 319 species, niphargoids are the most diverse Palearctic hypogean amphipods, which include also a few epigean taxa. They are distributed through central and particularly southeastern Europe, where they exhibit high levels of endemism in karst systems. More than 305 species of *Niphargus* have been described so far, and this is currently the largest freshwater amphipod genus (Fišer et al. 2005, Väinölä et al. 2008). Esmaeili-Rineh and Sari (2010) listed several localities for *Niphargus* in Iran: Dimeh spring in Chaharmahal and Bakhtiari, Brolan spring in West Azarbayjan, Sasan River in Fars, Ghor-Ghale cave in Kermanshah, Razbashi spring in Lorestan, Ghaemshahr and Danial Cave in Mazandaran and Cheshmeh-Siah in Koh-

giluyeh and Boyer-Ahmad Provinces. However, the identification data haven't been published for all of them so far.

Freshwater amphipods from Iran include the family Gammaridae with 18 species (Zamanpoore et al. 2011, Semsar-Kazerooni et al. 2016) and Niphargidae with 10 species of the single genus *Niphargus*. All Iranian *Niphargus* have been recorded from caves and karstic springs.

Family Niphargidae Bousfield, 1977

***Niphargus alisadri* Esmaeili-Rineh & Sari, 2013**

Status: **troglobiont**.

Records: Alisadr Cave (Hamedan Province) (Esmaeili-Rineh and Sari 2013). Fig. 1, locality 5.

***Niphargus bisitunicus* Esmaeili-Rineh, Sari & Fišer, 2015**

Status: **troglobiont**.

Records: Sarab-e-Bisitun (Kermanshah Province) (Esmaeili-Rineh et al. 2015). Fig. 1, locality 10.

***Niphargus borisi* Esmaeili-Rineh, Sari & Fišer, 2015**

Status: **troglobiont**.

Records: Belqis Spring (Kohgiluyeh and Boyer-Ahmad Province) (Esmaeili-Rineh et al. 2015). Fig. 1, locality 4.

***Niphargus daniali* Esmaeili-Rineh & Sari, 2013**

Status: **troglobiont**.

Records: Danial Cave (Mazandaran Province) (Esmaeili-Rineh and Sari 2013). Fig. 1, locality 6.

***Niphargus darvishi* Esmaeili-Rineh, Sari & Fišer, 2015**

Status: **troglobiont**.

Records: Dimeh Spring (Chaharmahal and Bakhtiari Province) (Esmaeili-Rineh et al. 2015). Fig. 1, locality 12.

***Niphargus kermanshahi* Esmaeili-Rineh, Heidari, Fišer & Akmal, 2016**

Status: **troglobiont**.

Records: Kangarshah Spring close to Sahneh City (Kermanshah Province) (Esmaeili-Rineh et al. 2016). Fig. 1, locality 13.

***Niphargus khayyami* Hekmatara, Zakšek, Heidari Baladehi & Fišer, 2013**

Status: **troglobiont**.

Records: Ghoori-Ghaleh Cave (Kermanshah Province) (Hekmatara et al. 2013). Fig. 1, locality 8.

***Niphargus khwarizmi* Hekmatara, Zakšek, Heidari Baladehi & Fišer, 2013**

Status: **troglobiont**.

Records: Cheshmeh Kahriz (Qanat) (East Azarbayjan Province) (Hekmatara et al. 2013). Fig. 1, locality 7.

***Niphargus sharifi* Esmaeili-Rineh, Sari & Fišer, 2015**

Status: **troglobiont**.

Records: Sarab-e-Robat (Lorestan Province) (Esmaeili-Rineh et al. 2015). Fig. 1, locality 11.

***Niphargus valachicus* Doboreanu & Manolache, 1933**

Status: **troglobiont**.

Records: unidentified cave near Ghaem Shahr (Mazandaran Province) (Karaman 1998). Fig. 1, locality 9.

Order Isopoda Latreille, 1817

Suborder Oniscidea Latreille, 1802

The order Isopoda contains over 10,000 species worldwide. Around 4,500 marine species are found mostly on the seabed; 500 species live in fresh water, while another 5,000 species from suborder Oniscidea are terrestrial (Schotte et al. 2016). The checklist of Oniscidea of Iran has not been published yet, but there are more than 40 recorded species from the country. Four species of this order have been listed here, including one troglobiont.

Family Agnaridae Schmidt, 2002

***Protracheoniscus faramarzi* Kashani, Dashan & Sadeghi, 2016 (in press)**

Status: **troglophile**.

Records: Shafagh Cave (Fars Province) (Kashani et al. 2016. In press).

***Protracheoniscus gakalicus* Kashani, Malek Hosseini & Sadeghi, 2013**

Status: **troglobiont**.

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (Kashani et al. 2013). Fig. 1, locality 2.

Family Porcellionidae Brandt, 1831***Agabiformius lentus* (Budde-Lund, 1855)**

Status: **trogloxene**.

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (Kashani et al. 2013).

***Porcellionides pruinosus* (Brandt, 1833)**

Status: **trogloxene**.

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (Kashani et al. 2013).

Class Maxillopoda Dahl, 1956**Order Cyclopoida Burmeister, 1834****Family Cyclopidae Rafinesque, 1815*****Diacyclops cf. crassicaudis* (Sars, 1863)**

Status: **troglophile**.

Records: Kiler Cave (Kohgiluyeh and Boyer-Ahmad Province) (present study). Species was identified by Dr. Frank Fiers from the Royal Belgian Institute of Natural Sciences.

Subphylum Hexapoda Latreille, 1825**Class Entognatha Stummer-Traunfels, 1891****Order Entomobryomorpha Börner 1913**

There are more than 8,600 described species of collembola worldwide (Bellinger et al. 2016), of which, more than 400 are hypogean (Romero 2009). The collembolan fauna of Iran is poorly known, it consists of 112 species, belonging to 18 families and 57 genera (Shayanmehr et al. 2013). There has been no detailed study

of cavernicolous collembola in Iran. Three species which have been listed below had been previously reported from soil and leaf litter (Shayanmehr et al. 2013). Specimens were identified according to Fjellberg (2007), by Dr. Masoumeh Shayan Mehr (Sari University of Agricultural Sciences and Natural Resources, Sari, Mazandaran, Iran).

Family Cyphoderidae Börner, 1913

***Cyphoderus albinus* (Nicolet, 1842)**

Status: **troglophile**.

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (present study).

Family Entomobryidae Schäffer, 1896

***Heteromurus nitidus* (Templeton, 1835)**

Status: **troglophile**.

Records: Deh Sheikh (Pataveh) Cave, Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (present study).

***Pseudosinella octopunctata* (Boerner, 1901)**

Status: **troglophile**.

Records: Kiler Cave (Kohgiluyeh and Boyer-Ahmad Province) (present study).

Class Insecta Linnaeus, 1758

Order Blattodea Brunner von Wattenwyl, 1882

To date, over 4,500 cockroach (order Blattodea or Blattaria) species have been reported from different parts of the world. The cockroach fauna of Iran includes three families, 14 genera, and 26 species (Hashemi-Aghdam and Oshaghi 2015). Many geographical regions of the country have not been studied yet, hence a systematic research is required to reveal the real cockroach biodiversity of the country. They were observed as guanophilic animals in most of Iranian caves and in some cases with a high density of populations. However, these cavernicolous cockroaches haven't been studied so far. Adaptations to life in darkness such as very long antennae and long legs with numerous sensory hairs and setae, have been observed in some populations.

Family Blattidae Latreille, 1810***Shelfordella* cf. *monochroma* (Walker, 1871)**

Status: **troglophile**.

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (Tahami and Sadeghi 2015).

Family Polyphagidae Saussure, 1864***Polyphaga aegyptica* (Linnaeus, 1758)**

Status: **troglophile**.

Records: Rood Fargh Cave (Kerman Province) (Tahami and Sadeghi 2015).

Order Coleoptera Linnaeus, 1758

There are over 330,000 species of beetles in the world; 1,927 terrestrial and 32 aquatic troglobionts have been described so far (Gibert and Deharveng 2002). The checklists of most families in Iran are not available.

Family Carabidae Latreille, 1802

Azadbakhsh & Nozari (2015) listed 955 species and subspecies in 155 genera, belonging to 26 subfamilies of Carabidae from Iran. Here we have listed 8 species from caves.

***Abacetus zarudnyi* Tschitschérine, 1901**

Status: **troglophile**.

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2016a).

***Bembidion (Ocyturanus) parsorum* Netolitzky, 1934**

Status: **trogloxene**.

Records: Nevel Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2016a).

***Duvalius kileri* Muilwijk & Malek Hosseini, 2016**

Status: **troglophile**.

Records: Kiler Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2016a).

***Laemostenus (Antisphodrus) aequalis* Muilwijk & Malek Hosseini, 2016**

Status: **troglophile**.

Records: Kiler Cave, Deh Sheikh (Pataveh) Cave, Nevel Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2016a).

***Laemostenus (Antisphodrus) bulirschi* Dvořák, 1995**

Status: **troglophile**.

Records: unidentified cave in Elburz, Demavend (Lohajr and Mlejnek 2007).

***Laemostenus (Antisphodrus) deconincki* Casale & Quéinnec, 2001**

Status: **troglophile**.

Records: Gamasiab Cave (Hamadan Province) (Casale and Quéinnec 2001), unidentified cave (Lorestan Province) (Lohajr and Mlejnek 2007).

***Laemostenus (Antisphodrus) glasunowi* Semenov, 1895**

Status: **troglophile**.

Records: unidentified cave in Elburz, Demavend (Mazandaran Province) (Lohajr and Mlejnek 2007).

***Paratachys fulvicollis* (Dejean, 1831)**

Status: **troglophile**.

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek Hosseini et al. 2016a).

Family Leiodidae Fleming, 1821

This family has not been studied in Iran so far. Less than 5 species are known from the country. Here we have listed one species from a cave.

***Eocatops beroni* Szymczakowski, 1976**

Status: **troglophile**.

Records: Shapur Cave (Fars Province) (Szymczakowski, 1976).

Family Ptinidae Latreille, 1802

Currently, about 220 genera and 2,200 species of spider beetles are known in the world. Several ptinids have been previously reported from caves, mostly in Europe (Arango and Young 2012). However, little is known about the spider beetle fauna of Iran.

***Niptus hololeucus* (Faldermann, 1835)**

Status: **troglophile**.

Records: Kangohar Cave (Fars Province) (Dashan et al. 2014a).

***Gibbium aequinoctiale* Boieldieu, 1854**

Status: **troglophile**.

Records: Kangohar Cave, Shafagh Cave, Tadovan Cave, Sahlak Cave (Fars Province) (Dashan et al. 2014b).

Family Salpingidae Leach, 1815

About 45 genera and 300 species are recognized worldwide, of which, a single troglophile species has been listed here (Sadeghi et al. 2014).

***Aglenus brunneus* (Gyllenhal, 1813)**

Status: **troglophile**.

Records: Tadovan Cave (Fars Province) (Sadeghi et al. 2014).

Family Staphylinidae Lameere, 1900

The family Staphylinidae, or rove beetles, with 56,768 described species in 3,624 genera and 33 subfamilies, is one of the most diverse families of animals. Staphylinidae of Iran contains 594 species and subspecies in 150 genera belonging to 13 subfamilies. Amongst those, 104 species and subspecies (17,5 %) are known only from Iran (Anlas and Newton 2010).

***Quedius iranicus* Coiffait, 1976**

Status: **troglophile**.

Records: Bishapur, Shapur Cave (Fars Province) (Coiffait 1976, 1978, Bordoni and Oromi 1998, Herman 2001, Smetana 2004).

***Stenus guttula* Muller, 1821**

Status: **trogloxene**.

Records: Behesht Makan Cave (Fars Province) (Dashan et al. 2014b).

***Stenus limicola* Korge, 1967**

Status: **trogloxene**.

Records: Behesht Makan Cave (Fars Province) (Dashan et al. 2014b).

Family Tenebrionidae Latreille, 1802

Darkling beetles, with more than 15,000 known species are one of the most common families of the order Coleoptera. The fauna of Iranian Tenebrionidae is considered poorly studied (Ghahari and Bunalski 2011). The most common genus in Iranian caves is *Blaps* Fabricius, 1775. In some caves this beetle was observed in high numbers and in all zones.

***Blaps variolaris* Allard, 1880**

Status: **troglophile**.

Records: Behesht Makan Cave, Dalkhoon Cave, Sahlak Cave, Tadovan Cave, Kangohar Cave (Fars Province) (Dashan et al. 2014b), Kiler Cave, Gakal Cave, Deh Sheikh (Pataveh) Cave (Kohgiluyeh and Boyer-Ahmad Province) (present study).

***Trachyderma christophi* Faust, 1875**

Status: **trogloxene**.

Records: Neyneh Cave (Kohgiluyeh and Boyer-Ahmad Province) (present study). The species was identified by Dr. Wolfgang Schawaller from the State Museum of Natural History, Stuttgart, Germany.

Order Diptera Linnaeus, 1758

Here, we have only mentioned ectoparasite Diptera that were collected from bats. The most conspicuous bat ectoparasites are the bloodsucking nycteribiid and streblid flies that are obligatory ectoparasites of bats (Marshall 1982, Theodor 1967). Till now only very limited studies have been done on the ectoparasites of bats in Iran (Benda et al. 2012). Here, 10 species from 6 genera and 2 families of Diptera have been listed.

Family Nycteribiidae Samouelle, 1819***Eucampsipoda hyrtlai* Kolenati, 1856**

Status: **bat ectoparasite.**

Records: Shafagh Cave (Fars Province) (Malek-Hosseini et al. 2016b).

***Nycteribia pedicularia* Latreille, 1805**

Status: **bat ectoparasite.**

Records: Neyneh Cave (Kohgiluyeh and Boyer-Ahmad Province), Shafagh Cave (Fars Province) (Malek-Hosseini et al. 2016b).

***Nycteribia schmidlii* Schiner, 1853**

Status: **bat ectoparasite.**

Records: Mozduran Cave (Razavi Khorasan Province) (Kock 1983), Tadovan Cave (Fars Province) (Benda et al. 2012), Gakal Cave, Neyneh Cave and Kiler cave (Kohgiluyeh and Boyer-Ahmad Province), Shafagh Cave (Fars Province) (Malek-Hosseini et al. 2016b).

***Nycteribia vexata* Westwood, 1835**

Status: **bat ectoparasite.**

Records: Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (Malek-Hosseini et al. 2016b).

***Penicillidia conspicua* Speiser, 1901**

Status: **bat ectoparasite.**

Records: Tadovan Cave (Fars Province), Dashkahul Cave (Ardabil Province) (Benda et al. 2012), Kiler Cave (Kohgiluyeh and Boyer-Ahmad Province), Tadovan Cave (Fars Province) (Malek-Hosseini et al. 2016b).

***Penicillidia dufourii* (Westwood, 1835)**

Status: **bat ectoparasite.**

Records: Tadovan Cave (Fars Province), Dashkahul Cave (Ardabil Province) (Benda et al. 2012), Kiler Cave, Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province), Shafagh Cave (Fars Province) (Malek-Hosseini et al. 2016b).

***Phthiridium biarticulatum* Hermann, 1804**

Status: **bat ectoparasite.**

Records: Mozduran Cave (Razavi Khorasan Province) (Kock 1983), Dashkahul Cave (Ardabil Province) (Benda et al. 2012), Tadovan Cave, Charkhab Cave (Fars Province) (Malek-Hosseini et al. 2016b).

***Stylidia biarticulata* Hermann, 1804**

Status: **bat ectoparasite.**

Records: Mozduran Cave (Razavi Khorasan Province) (Kock 1983).

Family Streblidae Kolenati, 1863

***Brachytarsina alluaudi minor* Falcoz, 1923**

Status: **bat ectoparasite.**

Records: Charkhab Cave (Fars Province) (Malek-Hosseini et al. 2016b).

***Brachytarsina flavipennis* Macquart, 1851**

Status: **bat ectoparasite.**

Records: Mozduran Cave (Razavi Khorasan Province) (Kock 1983), Tadovan Cave (Fars Province) (Benda et al. 2012), Tadovan Cave (Fars Province) (Malek-Hosseini et al. 2016b).

Order Hemiptera Linnaeus, 1758

Family Cimicidae Latreille, 1802

***Stricticimex namru* Usinger, 1960**

Status: **bat ectoparasite.**

Records: Dehloran Cave (Ilam Province) (Benda et al. 2012).

Order Siphonaptera Latreille, 1825

Family Ischnopsyllidae Wahlgren, 1907

***Ischnopsyllus dolosus* Dampf, 1912**

Status: **bat ectoparasite.**

Records: Dashkasan Cave, Dashkahul Cave (Ardabil Province) (Benda et al. 2012).

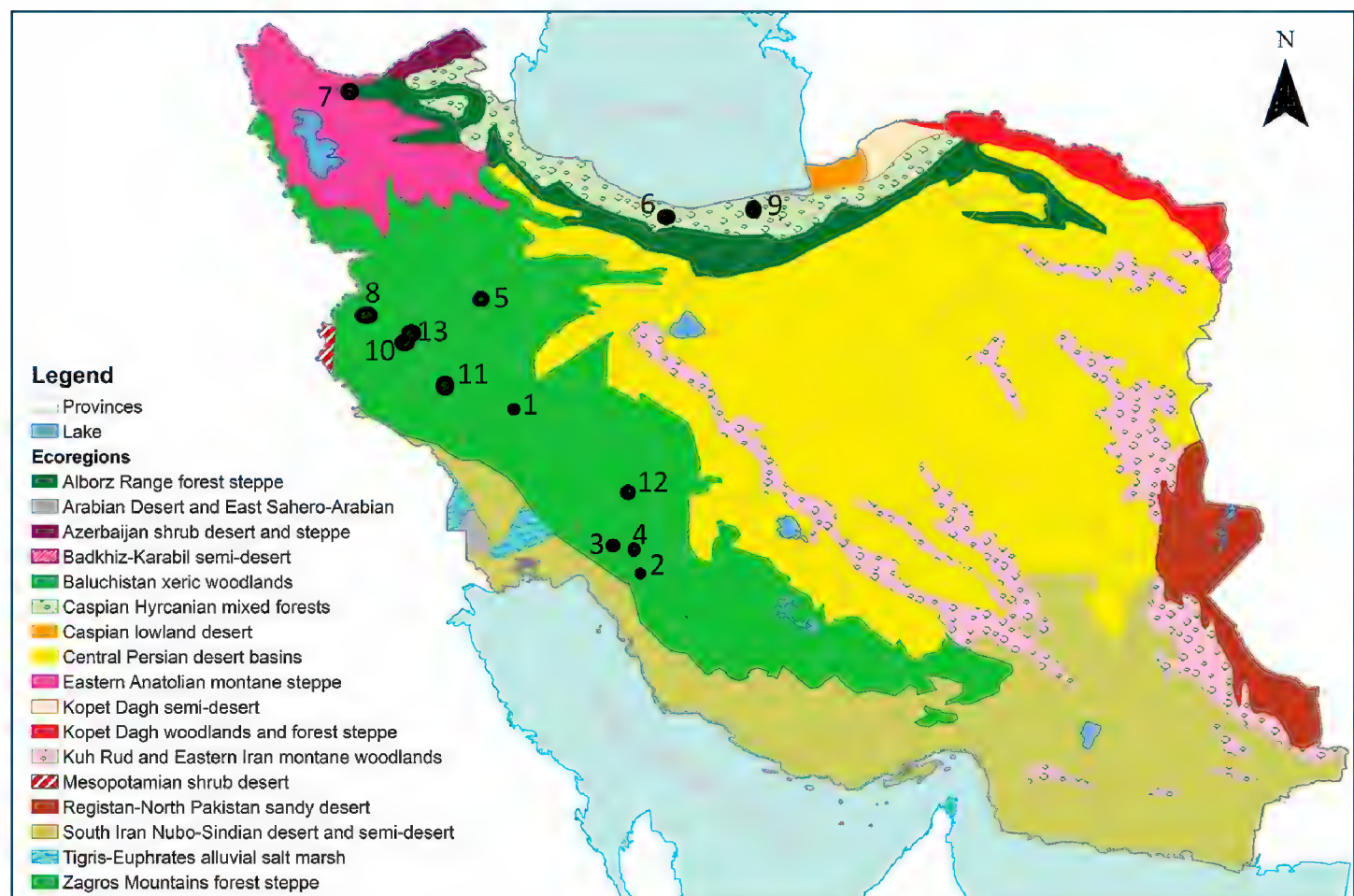


Figure 1. Map of terrestrial ecoregions in Iran, showing the distribution of troglobiote organisms (16 species). Map derived from WWF (Olson et al. 2001) and Safaei-Mahroo et al. (2015). **1** Loven Cave (Lorestan Province) (33°04'N, 48°35'E) *Garra typhlops*; *G. lorestanensis*; *Paracobitis smithi* **2** Gakal Cave (Kohgiluyeh and Boyer-Ahmad Province) (30°18'N, 51°09'E) *Protracheoniscus gakalicus*; *Trilacuna qarzi* **3** Neyneh Cave (Kohgiluyeh and Boyer-Ahmad Province) (30°40'N, 50°2'E) *Chiraziulus troglopersicus* **4** Belqais Spring (Kohgiluyeh and Boyer-Ahmad Province) (30°45'N, 50°44'E) *Niphargus borisi* **5** Alisadr Cave (Hamedan Province) (35°16'N, 48°17'E) *Niphargus alisadri* **6** Danial Cave (Mazandaran Province) (36°41'N, 50°53'E) *Niphargus daniali* **7** Cheshmeh Kahriz (Qanat) (East Azarbayjan Province) (38°41'N, 46°10'E) *Niphargus khwarizmi* **8** Ghoori-Ghaleh Cave (Kermanshah Province) (34°53'N, 46°30'E) *Niphargus khayyami* **9** unidentified cave near Ghaem Shahr (Mazandaran Province) *Niphargus valachicus* **10** Sarab-e- Bisitun (Kermanshah Province) (34°25'N, 47°28'E) *Niphargus bisitunicus* **11** Sarab-e-Robat (Lorestan Province) (33°35'N, 48°18'E) *Niphargus sharifi* **12** Dimeh Spring (Chaharmahal and Bakhtiari Province) (32°30'N, 50°13'E) *Niphargus darvishi* **13** Kangarshah Spring close to Sahneh City (Kerman-shah Province) (34°36'N, 47°39'E) *Niphargus kermanshahi*

Discussion

In our checklist, we compiled faunal lists of subterranean arthropods for Iranian caves based on scattered published literature together with unpublished data from our own collections. There are some ongoing projects addressing issues of biodiversity that will improve our knowledge of the cave fauna in this vast country, e.g. studies of cavernicolous pseudoscorpions, myrmecophilid crickets, oniscid isopods and niphargid amphipods by students of the University of Shiraz and Razi University of Kermanshah are being carried out. Moreover, there are other groups of cavernicolous arthropods in our collections that we did not list here because of incomplete identification, e.g. some species of Collembola, Coleoptera, Orthoptera (Grylloidea), Crustacea, Myriapoda, Araneae, Pseudoscorpiones and Acari. Ac-

According to our investigations, caves of Alborz and Zagros chains are rich in fauna. All Iranian troglobionts were described from the central and northern parts of Zagros and northern slopes of Alborz, which are mostly forested. About 10 species of troglomorphic crustaceans from Zagros caves and karstic springs are waiting to be described. The Zagros region exemplifies the continental variant of the Mediterranean climate pattern, while the northern slopes of Alborz are distinctly humid. So, these areas have a high level of productivity. The low species richness of Iranian caves is not realistic and it is due to a lack of comprehensive studies of all taxa (as a comparison, Sket et al. (2004) reported more than 975 terrestrial and 650 aquatic obligate subterranean species for the Balkan Peninsula).

An important problem is related to the identification keys for cavernicolous animals. To date, all studies have been sporadic. There is an ongoing comprehensive study on *Niphargus* of Iranian caves by Dr. Cene Fišer from University of Ljubljana, Slovenia with Iranian collaborators. The complete keys are needed to help future researchers.

From all 16 identified troglobiont species of Iran (3 terrestrial, 13 aquatic), 13 are arthropods, and out of these, 11 are crustaceans and 10 belong to the genus *Niphargus* (Niphargidae). From all 89 species of this checklist (from 42 caves and 5 karstic springs), Araneae with 29 species and Coleoptera with 17 species are dominant groups. A problem with some literature records are ambiguous names and localities of some caves that need to be clarified in further studies. Our studies about cave fauna should lead to decisions about conservation approaches. Unfortunately, based on our exploration and some other reports from caving groups, several caves have already been destroyed by human activities, which could cause drastic changes in food chains in these habitats, or even species extinction.

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